

Quality of Major/ Minor Crops

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Hybrid and N Fertilization Affect Corn Silage Yield and Quality

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With 5 tables

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Abstract

We determined the effect of N fertilization on dry matter (DM) yield, predicted milk yield, and forage quality of fresh (green chopped) and ensiled forage of two brown midrib (BMR) hybrids, a leafy hybrid, and a conventional silage hybrid. Increasing N rates from 0 to 200 kg ha⁻¹ increased corn grain, stover and whole plant DM yield and milk yield. The forage yield and quality response to N was similar for all hybrids. Nitrogen fertilization increased forage crude protein (CP) concentration but had little effect on other forage quality components. BMR hybrids, F377 and F657, had the lowest grain, stover and whole plant yield but had the highest digestibility and predicted milk yield Mg⁻¹ of forage. Predicted milk yield ha⁻¹ was similar for the BMR, leafy and conventional hybrids. Ensiling reduced starch concentration compared with green chopped forage, but effects on other forage quality variables were less consistent. Hybrid and N fertilization effects were similar for green chopped and ensiled corn forage.

Key words: brown midrib hybrids — Corn (*Zea mays* L — green chop nutritive value — silage nutritive value

Introduction

Corn silage is a major source of nutrients in dairy cow rations. To increase energy intake and maximize milk production, corn hybrids have been developed with higher forage quality (Allen et al. 1997, Darby and Lauer 2002). Brown midrib (BMR) hybrids with low lignin levels have been shown to have higher neutral detergent fibre (NDF) digestibility and to result in higher dry matter intake and milk production compared with conventional hybrid entries but their DM yields are frequently less than for conventional hybrids (Oba

and Allen 1999, Ballard et al. 2001). Hybrids with enhanced leafiness have also been marketed for improved forage quality and enhanced animal performance, but these hybrids have not consistently had superior forage quality or resulted in higher milk production than conventional hybrids (Kuehn et al. 1999, Ballard et al. 2001, Nennich et al. 2003).

Plant respiration and microbial activity during ensiling have potential to decrease the digestibility and increase the fibre and protein fractions of corn silage (Roth and Undersander 1996). The extent of these changes is greatly influenced by the ensiling methods and the characteristics of the ensiled forage. Therefore, it appears likely that the relative quality of corn hybrids differing in forage quality traits like digestibility or starch concentration has potential to change during ensiling. However, several studies have reported no differences in corn hybrid ranking for forage quality parameters such as NDF digestibility, NDF, or crude protein (CP) concentration when corn forage was fresh or ensiled (Hunt et al. 1993, Ballard et al. 2001, Darby and Lauer 2002).

Nitrogen is an essential nutrient for corn growth and development. Previous research has consistently shown responses in corn silage DM yield to N fertilization. Types of responses depend on the inherent soil N mineralization capacity of a soil. For example, O'Leary and Rehm (1990) showed that for a conventional corn hybrid whole plant DM yield increase was linear at three sites and curvilinear at five sites. From a forage quality standpoint, N fertilization has consistently increased whole plant

CP concentration (O'Leary and Rehm 1990, Cox and Cherney 2001) but effects on other forage quality variables are less consistent or have not been investigated. Cox and Cherney (2001) reported that increasing N fertilization linearly increased *in vitro* true digestibility (IVTD) but effects on NDF concentration were inconsistent. Although N fertilization plays a large role in regulation of carbohydrate partitioning within corn plants there is no information comparing its effect on forage quality of corn hybrids with diverse quality traits. Our objective was to determine the effect of N fertilization on DM yield, predicted milk yield, and forage quality of fresh (green chopped) and ensiled forage of two BMR hybrids, a leafy hybrid and a conventional hybrid.

Materials and Methods

Field experiments were conducted in 2000 and 2001 at Rosemount (44°43'N; 93°06'W) and Waseca (44°04'N; 93°31'W), MN on a Waukegan silt loam (fine-silty over sandy-skeletal, mixed mesic Typic Hapludoll) and a Webster clay loam (fine-loamy, mixed, mesic Aquic Haplodoll), respectively. The soil pH (6.5–7), exchangeable K ($>350 \text{ kg ha}^{-1}$) and Bray-1 P ($>40 \text{ kg ha}^{-1}$) at both locations was not limiting for corn growth. A 105 kg ha^{-1} N rate is recommended for corn production following soybean (*Glycine max* L.) on these soils (Randall et al. 2003).

The field experimental design was a randomized complete block with a split-split-plot restriction and three replicates at both Rosemount and Waseca. Nitrogen rates were whole plots, corn hybrids were sub-plots and green chopped vs. ensiling samples were sub-subplots. Whole-plot treatments were four N fertilizer rates (0, 50, 100 and 200 kg ha^{-1}) and sub-subplots were corn hybrids. Corn hybrids were TMF 108 (a hybrid marketed as leafy); F377 and F657 (BMR hybrids); and 3730 (a conventional Pioneer hybrid).

The experimental sites were chisel plowed in fall of the previous year. In late April, the sites were disked and N fertilizer (urea) was broadcast and incorporated. On 5 May, corn was planted to achieve populations of 30 000 plants ha^{-1} in four row plots with rows spaced 12 cm apart. Standard chemical and cultural practices controlled weeds.

Total forage (grain and stover) yield was measured by harvesting and weighing a 3 m section of the middle two rows of each four-row plot when the average whole moisture of all hybrids reached a target whole plant moisture level of 60 %. Ten whole plants from harvested rows were randomly selected and chopped to a 1-cm length with a modified portable wood chipper. The chopped forage was homogenously mixed and a 1 kg sample was dried at 60 °C for 48 h in a forced-air dryer for DM determination. Following weighing, a 0.25 kg subsample was ground and saved for forage quality analysis. The

remainder of the harvested plot area was separated into stover and grain. The grain was dried at 60 °C, shelled from the cob and grain yields were adjusted to 150 g kg^{-1} moisture.

A 3 kg sample of the wet chopped forage from the harvest rows was immediately compressed into a polyvinyl chloride mini-silo (15 cm diameter by 50 cm long cylinder) that was stopper at both ends and contained a Bunsen valve to allow fermentation gas release. The artificial silos were stored indoors for 2 months at 15 °C. The mini-silos were opened and the sample was dried and ground as described for green chopped forage.

Spectra for near infrared reflectance spectroscopy (NIR) analysis were collected with a Foss (Foss North America Inc., Eden Prairie, MN, USA)¹ model 6500 scanning monochromator with a range of 400–2500 nm. Previously developed equations predicted CP, ADF and NDF in green chop samples and ash in both green chop and ensiled forage, while new equations were made for starch and IVTD in green chopped forage and for CP, NDF, starch and IVTD of ensiled forage. Samples were selected from the entire population based on spectral differences within the samples using the Infrasoft International (ISI, Port Matilda, PA, USA)¹ WINISI 2 software program with the select samples option. Conventional chemical analyses [CP (Kjeldahl N $\times 6.25$), NDF and IVTD (Goering and Van Soest 1970), starch (Hall 2000) and ash (Munter and Grande 1981)] were performed on the selected samples. Equations for NIR were developed using the spectral data combined with the chemical data in the WINISI software option, 'Global Calibration' using modified partial least squares regression and two passes to eliminate outliers (Shenk and Westerhaus 1991). A first derivative math treatment of 1,4,4,1 was used for all equations. Separate NIR equations were developed for green chopped and ensiled forage. All previously made equations were monitored (Marten et al. 1989). All new equations showed satisfactory development statistics for standard error of cross validation and explained variance. NDF digestibility was calculated using NDF and IVTD (Darby and Lauer 2002). Predicted milk yield Mg^{-1} of forage and milk yield ha^{-1} were calculated using Milk 2000 (Schwab and Shaver 2001).

All data variables were analysed using analysis of variance (SAS; SAS Institute, Inc. 1996). The N rate effect at each location was partitioned into linear and quadratic effects using orthogonal polynomials for unequal intervals. When significant linear or quadratic effects of N rate occurred, the mean values of the yield and forage quality variables were plotted against N rate. Equations were fitted to the lines using stepwise regression (SAS Institute, Inc. 1996).

¹ Mention of a proprietary product does not constitute a recommendation or warranty of the product by the University of Minnesota or USDA-ARS and does not imply endorsement and exclusion of other suitable products.

Results and Discussion

Green chopped vs. ensiled forage

The largest and most consistent change because of ensiling occurred for starch concentration that declined with ensiling (Table 1). The concentration of other forage quality measures was similar at Rosemount, but at Waseca, ensiling lowered NDF and increased IVTD and NDFD. Ensiling typically results in some loss in DM because of plant respiration that can reduce carbohydrate fractions. We cannot explain the large change in starch concentration because we rapidly sealed the mini-silo after filling and upon opening of mini-silos we observed no spoilage or adverse smells. The silage had an average pH of 3.7. However, results on

effects of ensiling on forage quality components from previous published mini-silo research have also been inconsistent. Darby and Lauer (2002) reported lower CP, NDF, IVTD and NDF digestibility (NDFD) with ensiling of corn while Ballard et al. (2001) reported small increases in NDF and decreases in starch and IVTD while NDFD did not change.

We compared the forage quality of green chopped vs. ensiled forage to determine the potential for interaction of N rate and hybrid treatment with forage type (green chop vs. ensiling). No interactions ($P \leq 0.05$) of forage type with hybrid or N fertilizer treatments occurred. Therefore, N fertilization rate and hybrid data are shown only for green chopped forage.

Table 1: Crude protein (CP), neutral detergent fibre (NDF), *in vitro* true digestibility (IVTD), NDF digestibility (NDFD), and starch content of green chopped and ensiled whole corn plants at Rosemount and Waseca, MN¹

Sample type	CP	NDF	IVTD	NDFD	Starch
Rosemount					
Green chopped	75	415	754	405	381
Ensiled	71	400	770	426	225
LSD 0.05	NS	NS	NS	NS	32
Waseca					
Green chopped	67	436	739	405	341
Ensiled	68	413	774	452	229
LSD 0.05	NS	20	17	20	14

Values given as g kg⁻¹ of dry matter.

¹Values averaged over four hybrids and four N fertilizer rates.

Nitrogen fertilization

Nitrogen fertilization had a large effect on corn grain, stover and whole plant yield at both locations (Tables 2 and 3). The positive response in grain and whole plant DM yield to increasing N rate from 0 to 200 kg ha⁻¹ was quadratic at both locations, while stover yield response was linear. The milk yield Mg⁻¹ of forage response was linear, while the milk yield ha⁻¹ response was quadratic. A quadratic response in yield ha⁻¹ was expected for the N rates applied to these soils (Randall et al. 2003). The response to N was similar for all hybrids at both locations for grain stover and whole plant yield (i.e. no N rate by hybrid interaction). Nitrogen fertilization had no effect on whole plant moisture levels at harvest.

Table 2: Regression equations relating N fertilizer rate and grain, stover and whole plant dry matter yield (ton ha⁻¹) and milk yield (Mg⁻¹ and ha⁻¹)^{1,2}

Trait	Equation	R ²
Rosemount		
Grain DM yield	$[9.1 + 0.02 (\text{N rate})] - [8 \times 10^{-5} (\text{N rate})^2]$	0.99
Stover DM yield	$7.2 + 0.004 (\text{N rate})$	0.99
Whole plant DM yield	$[16.3 + 0.02 (\text{N rate})] - [8 \times 10^{-5} (\text{N rate})^2]$	0.99
Milk yield (kg Mg ⁻¹)	$1453.4 + 0.34 (\text{N rate})$	0.84
Milk yield (kg ha ⁻¹)	$[21\ 637 + 55.3 (\text{N rate})] - [0.205 (\text{N rate})^2]$	0.99
Waseca		
Grain DM yield	$[6.25 + 0.04 (\text{N rate})] - [1 \times 10^{-4} (\text{N rate})^2]$	0.99
Stover DM yield	$[6.75 + 0.02 (\text{N rate})] - [0.05 (\text{N rate})^2]$	0.98
Whole plant DM yield	$[12.9 + 0.06 (\text{N rate})] - [2 \times 10^{-4} (\text{N rate})^2]$	0.99
Milk yield (kg Mg ⁻¹)	$1429 - 0.13 (\text{N rate})$	0.94
Milk yield (kg ha ⁻¹)	$[16\ 968 + 71.4 (\text{N rate})] - [0.21 (\text{N rate})^2]$	0.99

¹N rates were 0, 50, 100, and 200 kg ha⁻¹.

²Averaged for four corn hybrids.

Table 3: The effect of N fertilization rate on grain, stover, and whole plant corn yield and milk production

N rate (kg ha ⁻¹)	Yield (ton ha ⁻¹)				
	Grain	Stover	Whole plant	Milk (kg Mg ⁻¹)	Milk (kg ha ⁻¹)
Rosemount					
0	9.1	7.2	16.3	1458	21691
50	10.1	7.4	17.5	1455	23747
100	10.7	7.6	18.2	1502	25228
200	10.6	8.0	18.6	1519	24484
LSD (0.05)	0.6	0.5	1.2	132	2010
Waseca					
0	6.3	6.7	12.9	1427	16941
50	7.8	7.6	15.4	1426	20075
100	9.0	8.0	17.0	1413	21918
200	8.8	9.0	17.8	1402	22704
LSD (0.05)	0.3	0.6	2.1	NS	235

Nitrogen fertilization had little effect on forage quality variables except for forage CP concentration. There was a significant linear increase in forage CP concentration in response to N fertilization at Rosemount [$CP = 58.5 + 0.09 (N \text{ rate})$, $R^2 = 0.95$]; and Waseca [$CP = 53.7 + 0.07 (N \text{ rate})$, $R^2 = 0.98$]. There was no N fertilization \times corn hybrid interaction for any yield or forage quality variable.

Corn hybrids

Corn hybrids differed in grain, stover and whole plant yields at both locations (Table 4). The most consistent effects occurred because the BMR

hybrids, F377 and F657, were among the lowest in grain, stover and whole plant yield at both locations. These results are consistent with previous reports (Ballard et al. 2001). Either TMF 108 or 3730 had the greatest grain, stover, or whole plant yields.

Because all corn hybrids were harvested when whole plant moisture levels reached an average of 60 %, moisture levels of hybrids at harvest varied. The TMF hybrid was drier than the other hybrids at each location. At Rosemount, whole plant moisture was 59 %, 65 %, 61 % and 62 % for TMF 108, F377, F657 and 3730, respectively; while at Waseca, moisture levels averaged 58 %, 65 %, 64 % and 64 %, respectively. Therefore, hybrid differences in forage quality may be confounded with moisture level as forage quality has been shown to decrease at moisture level < 60 % (Darby and Lauer 2002). TMF 108, the hybrid with the lowest moisture level at both locations, also consistently was among those entries with the lowest forage quality (Table 5).

The BMR hybrid F377 consistently had lower NDF and higher IVTD and NDFD than the other hybrids. The higher quality parameters of this BMR hybrid resulted in significantly higher milk Mg⁻¹ of forage than the other hybrids. These results are supported by the results from a feeding trial by Oba and Allen (1999) who reported that dairy cows fed BMR corn silage had greater milk production than cows fed conventional corn silage. Although the BMR hybrids had lower yields than the other hybrids, their higher quality resulted in

Table 4: Average grain, stover, whole plant yield and milk yields for four corn hybrids at Rosemount and Waseca, MN¹

Hybrid	Grain (tons ha ⁻¹)	Stover (tons ha ⁻¹)	Whole plant ² (tons ha ⁻¹)	Milk yield (kg Mg ⁻¹)	Milk yield (kg ha ⁻¹)
Rosemount					
TMF108	10.4	8.7	19.1	2523	48198
F377	9.5	7.6	17.1	2846	48670
F657	9.1	6.9	16.0	2865	45844
3730	10.0	7.8	17.8	2675	47612
LSD 0.05	0.5	0.7	0.6	124	NS
Waseca					
TMF108	8.6	9.6	18.2	2346	42693
F377	7.2	7.0	14.2	2800	39753
F657	7.2	7.9	15.1	2335	35252
3730	8.8	8.4	17.2	2416	41568
LSD 0.05	0.6	0.7	0.6	113	NS

¹Whole plant includes grain and stover.

²Values averaged for four N fertilizer rates.

Table 5: Crude protein (CP), neutral detergent fibre (NDF), *in vitro* true digestibility (IVTD), NDF digestibility (NDFD), starch, and ash content of green chopped whole corn plants at Rosemount and Waseca, MN¹

Hybrid	CP	NDF	IVTD	NDFD	Starch	Ash
Rosemount						
TMF108	68	431	728	369	353	41
F377	75	406	763	417	411	37
F657	74	419	766	442	380	42
3730	78	423	742	390	372	41
LSD 0.05	3	NS	15	22	23	3
Waseca						
TMF108	61	457	696	336	335	34
F377	72	423	776	470	334	45
F657	68	425	739	386	372	35
3730	68	472	720	407	289	48
LSD 0.05	3	17	14	12	20	1

Values given as g kg⁻¹ dry matter.

¹Values averaged over four N fertilizer rates.

similar milk (tons per acre) for all hybrids. These results for IVTD are consistent with those of Ballard et al. (2001) who reported that total forage digestibility for green chopped forage of a BMR hybrid was superior to that from a TMF and a conventional hybrid, but Ballard et al. (2001) also reported similar NDF and NDFD for a BMR hybrid compared with a leafy and conventional hybrids.

Conclusion

The lack of interactions among corn hybrid, N fertilization and ensiling treatments, ensures that producers can select hybrids based on forage quality results from green chopped forage and expect consistency in forage quality over a range of N fertility levels. Nitrogen fertilization increased grain and whole plant DM and milk yield of corn. While there was a linear increase in predicted milk yield Mg⁻¹ of forage, the quadratic relationship for yield of the whole plant and milk ha⁻¹ affirmed that N application above the recommendation rate had no effect on yield and was likely unprofitable.

Because of the potential to produce higher milk yields Mg⁻¹ of forage and similar milk production ha⁻¹ at lower DM yields compared with conventional entries, BMR hybrids have potential as silage crops. The higher milk production ha⁻¹ of BMR hybrids was associated with higher forage IVTD and NDFD compared with other entries.

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